

## CASING PATCHING TOOL

### 5 BACKGROUND OF THE INVENTION

The present invention relates to the installation of patches to seal holes in pipes generally, and more particularly to a method and apparatus for sealing perforations in steam or water injection oil wells.

10 Oil wells may be generally classified as being of one of three different types; production wells, steam injection wells, and water injections wells. Production wells are used to pump oil from an oil bearing formation. Steam injection wells serve to heat certain types of particularly thick oil and thereby aid  
15 production wells in extracting oil. Water injection wells operate on the principle that oil floats on water and therefore oil extraction may be aided by pumping water below an oil pool and thereby raising the level of the pool. Oil wells are typically made by drilling a borehole in an oil bearing  
20 formation. The borehole is typically about six to twenty inches in diameter and may range from about 400 to about 20,000 feet in depth. After drilling the borehole to a desired depth, a steel pipe or casing is installed in the borehole from the surface to the bottom of the hole. Such casings vary in diameter depending  
25 upon the application. Casings of three and one-half inches in outside diameter are one common size for steam injection wells. After installation of the pipe, cement is typically pumped down the pipe under substantial pressure so that the cement will exit the pipe at the bottom of the borehole and will flow to the  
30 surface, thereby filling the gap between the outside of the pipe and earthen inner wall of the borehole. Upon completion of the process an open pipe encased in cement runs from the surface to the bottom of the original earthen borehole.

35 *505 a17* In many oil bearing formations, the oil is very thick having a consistency similar to that of molasses. Oil of this type

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cannot effectively be pumped to the surface without first heating  
the oil to reduce its viscosity to a point where the oil is in  
5 a flowable state. It has long been standard practice in the oil  
industry to heat such thick oil by means of steam injection. In  
a steam injection oil well, perforations, for the injection of  
steam into the oil are created at predetermined intervals along  
that portion of the well casing that passes through the oil  
10 bearing formation. For example, if the last two hundred feet of  
an 1800 foot wellbore pass through an oil pool, four perforations  
will typically be made at 50 foot intervals along the casing.  
Typically, the perforations are about one quarter of an inch in  
diameter and are formed by "shaped" explosive charges which are  
15 lowered to the desired depths in the well. The shaped charges  
are capable of penetrating both the inner steel well casing <sup>and</sup> the  
outer concrete casing.

A common problem in steam injection oil wells is that as the  
oil is pumped from the well, the oil level drops and eventually  
20 uncovers the perforations. When this occurs steam enters the  
evacuated region formerly occupied by oil and forms what is known  
in the industry as a "steam chest." The loss of steam through  
uncovered perforations greatly reduces the efficiency of the well  
and in many cases where multiple perforations are uncovered the  
25 recovery of the remaining oil reachable by the well becomes cost  
prohibitive. In order to keep such wells productive, attempts  
have been made to develop methods of sealing the uncovered  
perforations. Perhaps the most common prior art approach to  
sealing perforations has been to form a sealing sleeve, where the  
30 sleeve comprises a cylindrical steel portion with rubber-like  
gasket material bonded to the outer surface of the steel sleeve.  
The sleeve and gasket typically have a combined thickness of  
about .5 inch. Thus, when deployed the sleeve creates a  
significant restriction in the diameter of a typical wellbore.  
35 Generally, for deployment, the sleeve is wrapped about an

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expansion device which is typically a mechanically operated expander plug and is subsequently lowered to the uncovered perforation. Upon reaching the perforation the sleeve is expanded to seal the perforation. Typically, the sleeve is held in place in the well casing by friction. Devices similar to the one described above except that an explosive charge is substituted for the expander plug have also been tried.

10 The prior art approaches suffer from several drawbacks, with the foremost being the reduction in the inside diameter of the wellbore in the region of the sealing sleeve. Such a reduction in diameter severely limits the types of downhole tools that may subsequently be deployed in the bore. In addition, since prior art sealing sleeves are wrapped about an expansion device, there is typically only a small amount of clearance between the outside diameter of the sealing sleeve and the inside diameter of the wellbore. As a consequence, any irregularity in the casing due to deposits or a slight bend in the casing will cause a typical prior art sealing patch to "hang up" or become wedged in the wellbore. Also, prior art sealing sleeves have been known to leak severely and, on rare occasions, slip in the bore and consequently uncover the perforation they were intended to seal. Further, the prior art sealing methods have proven to be relatively costly to employ.

What is needed therefore is a sealing device and method that can effectively seal a casing perforation with a relatively thin patch that does not significantly reduce the size of the borehole. Another highly desirable feature would be the ability to place a subsequent patch at a location below an existing patch. Preferably, such a device and method will also provide a mechanism for more securely adhering the patch to the wall of the wellbore, and will further be of relatively low cost to produce and deploy.

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SUMMARY OF THE INVENTION

5 The present invention casing patching tool overcomes many of the problems of the prior art by providing an apparatus and method for delivering a thin spirally wound or coiled patch possessing spring-like properties that effectively seals wellbore perforations without significantly reducing the bore's internal diameter. The patch is preferably formed from spring-steel and  
 10 uses spring tension to increase adherence to the wall of the wellbore. The invention provides the ability to place a subsequent patch at a location below an existing patch. Consequently each perforation in a steam injection well may be sealed as the level of oil in the formation drops and thereby  
 15 exposes the next lower perforation. Further, the present invention casing patching tool may be fabricated at relatively low cost and is comparatively easy to deploy and use.

20 The primary components of the invention preferably comprise a spirally wound metal patch, a patch delivery tool, and a patch rolling tool. The delivery tool further comprises a barrel and a plunger assembly, where the plunger assembly is slidably received within the barrel. Prior to use, the patch is wound into the form of a cylinder by means of the rolling tool and is loaded into the barrel of the delivery tool. To prevent  
 25 inadvertent deployment of the patch while lowering the delivery tool to the location of a perforation, a shear pin is used to hold the plunger assembly in a fixed position with respect to the barrel. To deploy the patch, hydraulic pressure is applied to the plunger assembly causing the barrel to shear the shear pin  
 30 and move upwardly with respect to the stationary plunger. The patch abuts the plunger and remains stationary while the barrel travels up the pull tube. At the end of its travel, the barrel will have slid entirely off the patch, thus freeing the patch within the wellbore. Upon deployment, the patch unwinds within  
 35 the wellbore and seals the perforation in the casing wall.

Spring tension tends to keep the patch securely fixed over the perforation. These and other features of the invention will become more apparent from the following detailed description of the invention, when taken in conjunction with the accompanying exemplary drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

10 FIG. 1 is a perspective view of the assembled delivery tool showing the relationship between the barrel and plunger assembly and further showing a patch loaded within the barrel in accordance with the present invention.

Fig. 2 is a perspective view of the plunger assembly shown in FIG. 1.

Fig. 3 is a perspective view of the barrel assembly shown in FIG. 1.

FIG. 4 is a top plan view of a sealing patch in accordance with the present invention.

20 FIG. 5 is a top plan view of a patch rolling tool in accordance with the present invention.

FIG. 6 is a side view, reduced in scale, of the patch of FIG. 4, after it has been rolled with the rolling tool of FIG. 5.

25 FIG. 7 is top view, reduced in scale, showing the spirally wound or coiled configuration of the patch of FIG. 4, after it has been rolled with the rolling tool of FIG. 5.

Fig. 8 is a detail view showing an exemplary D-shaped slot and clip for use in the rolling tool of FIG.5.

Fig. 9 is a detail view showing an exemplary D-shaped slot for use in the patch of FIG.4.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIG. 1, an exemplary embodiment of the casing  
 5 patching tool 10 is shown. The tool comprises a plunger assembly  
 12 and a plunger barrel 14. Also shown is a shear pin 18 which  
 locks the plunger assembly to the barrel while the delivery tool  
 is deployed to the location of a perforation. Deployment is  
 typically accomplished by lowering the delivery tool via a cable  
 10 to a predetermined depth within a borehole. Also shown is a  
 metal patch 16, which has been rolled or coiled and loaded into  
 the plunger barrel.

Referring now to FIGS. 2 and 3, the plunger assembly 12 and  
 the barrel 14 are shown in more detail. The plunger assembly  
 15 includes a plunger 20, a pull-tube 22, and a hydraulic fitting  
 24. The plunger is preferably cylindrical in configuration and  
 may have a bore 21 or may be solid. The plunger is sized to be  
 slidably received within a first bore 34 of the barrel 14.  
 Connected to the plunger is the pull-tube having upper and lower  
 20 ends 25 and 23 respectively. The pull-tube is a hollow tube  
 having a bore 31 through which pressurized fluid may pass. At  
 its lower end, the pull-tube includes a plurality of holes 28  
 through which the pressurized fluid may exit. Also formed in the  
 lower end of the pull-tube is a keyway or hole 32 for receipt of  
 25 the shear pin 18. The pull-tube is sized to be slidably received  
 within a second bore 36 of the barrel. The lower end of the  
 pull-tube is attached to the plunger substantially <sup>a</sup>long a common  
 longitudinal axis. The lower end may be attached to the plunger  
 by any known method including welding or threading the lower end  
 30 to a top surface 26 of the plunger. It is important to note that  
 the pull-tube is not in fluid communication with the interior  
 bore 21 of the plunger, when the plunger is so equipped. The  
 upper end of the pull-tube is connected to a hydraulic fitting  
 24, and the bore 31 of the pull-tube is in fluid communication  
 35 with a bore 30 of the hydraulic fitting. The upper end of the

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pull tube may be connected to the hydraulic fitting by any  
suitable means including welding or threading. The pull-tube and  
5 the hydraulic fitting may also be formed integrally, i.e., they  
may be integrally machined from a single piece of metal bar or  
tube stock. It is also possible, and may in some situations be  
desirable to integrally form the pull-tube with the plunger.

With particular reference to FIG. 3, the plunger barrel 14  
10 is an elongated hollow cylindrical member having upper and lower  
ends, 42 and 44 respectively, and the longitudinal first bore 34.  
The upper end of barrel is closed out by a top plate or barrel  
plug 40, which includes the second bore 36 for slidable receipt  
of the pull-tube 22. The barrel also plug also includes a hole  
15 38 for receipt of the shear pin 18. The lower end of the barrel  
is open to allow the plunger 20 and the pull-tube to be inserted  
into the barrel and is of sufficient length to house the metal  
patch 16. Preferably, the barrel is constructed of steel and the  
first bore 34 is hard chrome plated. The hard chrome plating  
20 both reduces friction within the barrel and resists corrosion.  
Generally, the components of the delivery tool should be  
constructed of steel or other materials capable of withstanding  
the environmental conditions typically found in a deep oil well.  
The borehole environment includes pressures in the range of about  
25 100-1000 psi and temperatures of about 200-500°F. Some boreholes  
also contain corrosive gasses with hydrogen sulfide and carbon  
dioxide being the most common. Borehole conditions tend to vary  
from oil field to oil field, however, these environments are well  
understood by those skilled in the art and materials suitable for  
30 use in such environments are also well known.

Referring now to FIGS. 4-5 and 8-9, the metal patch 16 of  
the present invention comprises a flat sheet of length "l," width  
"w," and of thickness "t." Generally, the patch should be  
35 comparatively thin with respect to its length and width in order  
to keep the reduction in the inside diameter of the wellbore to

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2 a minimum. The actual patch thickness is a function of the  
3 diameter of the wellbore and the yield and tensile strengths of  
4 the patch material. In general, as the wellbore diameter  
5 increases it is necessary to increase the thickness of the patch  
6 in order for the deployed patch to apply sufficient force to the  
7 wall of the wellbore to seal the perforation. In the exemplary  
8 embodiment, a patch of about 6 feet long, by about 3 feet wide,  
9 by about .008 inches thick was successfully used in a steam  
10 injection well having a casing with an outside diameter of about  
11 3.5 inches. It is expected that patches having a thickness in  
12 the range of about .004 to about .030 inches will effectively  
13 seal typical steam injection wells, which range in size from  
14 about 2 7/8 inches in diameter to about 7.0 inches in diameter.  
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16 Preferably, the width of the patch is sized to be about  
17 three times the circumference of the wellbore. This allows for  
18 about three wraps of the patch internally within the wellbore  
19 when the patch is deployed. Three wraps have been found  
20 sufficient to effectively seal a perforation, yet not  
21 significantly reduce the internal diameter of the wellbore. It  
22 is to be emphasized, that the dimensions given are exemplary only  
23 and are not meant to be limiting. The actual dimensions for a  
24 particular patch will vary depending on the size of the wellbore,  
25 the size of the perforation to be sealed, and the borehole  
26 environment.

27 The patch 16 includes an inside edge 56, which is engaged  
28 by a rolling tool 52, and an outside edge 58, the full length of  
29 which is in contact with the wall of the wellbore. The patch  
30 also includes a plurality of engagement slots 46, of  
31 predetermined spacing, which run along the length of the inside  
32 edge. The slots are engaged by a like number of slotted clips  
33 54, of like spacing, on the patch rolling tool 52. In the  
34 exemplary embodiment, the slots and engaging clips are generally  
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D-shaped in configuration. However, many other slot and clip arrangements are known and are suitable in this application.

5 Along the outside edge 58 of the patch 16, an optional pattern of holes 48 which may increase the frictional adherence of the patch against the wall of the well casing, may be added. The pattern of holes may run the entire length of the outside edge or may cover only a portion thereof. The function of the  
10 holes is to improve the sealing characteristics of the patch and it is presently believed that this goal is best met by placing a pattern of holes over only a portion of the outside edge. The size and spacing of the holes may vary depending upon the application. Further, additional testing may reveal that  
15 configurations other than circular holes provide for better adherence of the patch to the wall of the wellbore. Thus, it may prove desirable to make the holes square, triangular, or of some other pattern. In the exemplary embodiment, twelve holes of about one inch in diameter spaced apart about two inches from  
20 hole centerline to centerline were included at the midpoint of the outside edge of the patch. The inside edge 56 of the patch may also be optionally equipped with chamfers 50. The chamfers provide for deflection points which reduce the likelihood of the inside edge of the patch from deflecting or curling inwardly when  
25 deployed within a wellbore. Such inward deflection or curling is undesirable because it increases the likelihood of a downhole tool becoming caught or snagged on the patch.

Preferably the metal patch is constructed of spring-steel. Type 301 stainless steel in the full-hard condition is one  
30 suitable alloy that provides a desirable combination of spring-like properties and corrosion resistance. However, numerous other steel alloys and materials with spring-like properties are known in the art and may be substituted for spring-steel. Other potentially suitable materials include various plastics and  
35 carbon fiber composites and other structural composites. Also,

a non-metal coating may be added to the surface of stainless steel patches to reduce the likelihood of galvanic corrosion occurring between the stainless steel patch and the mild steel casing.

Referring now to FIG. 5, the patch rolling tool 52 may be formed from virtually any material in which clips 54 may be formed or attached. Suitable materials include steel, aluminum, or plastic bar, plate, or tube stock. Other materials are also suitable.

The apparatus of the present invention may be used as follows. Referring now to FIGS. 1-3, typically, the pull-tube 22 is attached to the plunger 20. Next the pull-tube is slid through the second bore 36 in the top plate or barrel plug 40. Next, the hydraulic fitting 24 is attached to the pull-tube. Subsequently, the plunger 20 is slid into the first bore 34 of the barrel 14 and the barrel plug is attached to the barrel thereby completing the delivery tool 10. In the exemplary embodiment, threaded connections were used to attach each component of the delivery tool.

Referring now to FIGS. 4-7, the slots 46 of the spring-steel patch 16 are engaged by the clips 54 of the rolling tool 52. The patch is then rolled along its width to form a coiled or spirally wound cylinder as shown in FIGS. 6 and 7. The patch may be secured in its coiled state via a patch restraining means, i.e., cords, bands, and the like to help load the patch in the barrel.

At this time, the shear pin holes 32 and 38, in the pull-tube 22 and barrel 14 respectively, are aligned and the shear pin 18 is inserted into the holes to fix the respective position of the pull-tube to the barrel. It should be noted that alignment of the pull-tube with the barrel defines an enclosed volume 60 between the top surface 26 of the plunger 20 and the top plate 40 of the barrel. Preferably, the holes 28 in the pull-tube will be located below the top plate and above the top surface of the

plunger. Subsequently, the coiled patch 16 is loaded into position within the barrel. Preferably, the patch should be  
 5 fully enclosed within the barrel and positioned adjacent to the plunger. As the patch is loaded into the barrel, the patch restraining means are removed and the patch will tend to uncoil slightly within the barrel creating a frictional force which  
 10 securely holds the patch in place. The delivery tool 10, loaded with a coiled patch, is now ready for delivery to the location of a perforation. It should be noted that often it may be easier to first load the patch into the barrel prior to sliding the plunger into the barrel and attaching the top plate.

The delivery tool 10 and patch 16 may be deployed within a  
 15 borehole using conventional wireline or coiled tube equipment or other lowering means well known to those skilled in the art of oil production. In addition to the downhole lowering means, a hydraulic fluid supply means must be connected to the delivery tool. Once the delivery tool has been lowered to a level  
 20 proximate to a perforation, the patch 16 may be deployed. To deploy the patch a pressurized gas or liquid is supplied to the delivery tool. Most hydraulic fluids and compressible gasses are suitable for operating the tool. Presently, when wireline equipment is used to lower the tool, gas is preferred. The gas  
 25 may be supplied by a gas generator which burns solid propellents to create high pressure gas source. Alternatively, compressed air or an inert gas may be supplied from a source such as a storage cylinder or a compressor. Presently, when coiled tubing is used as the lowering means, water is the preferred hydraulic  
 30 fluid as often it is readily available at well sites and presents fewer handling and contamination problems than other fluids.

Deployment is accomplished by supplying the high pressure  
 fluid (liquid or gas) to the hydraulic fitting 24. The fluid  
 traverses the bore 31 of the pull-tube 22 and exits the tube at  
 35 the plurality of holes 28 at the lower end of the tube 23. The

pressurized fluid fills the volume 60 defined by the top plate 40 of the barrel 14 and the top surface 26 of the plunger 20. As pressure builds up within the volume 60, the barrel is forced upwardly against the stationary plunger until the coiled metal patch 16 is free of the barrel. Upon deployment from the barrel the patch unwinds or uncoils within the borehole and seals the perforation in the casing wall. Since the length of the patch (about six feet in the exemplary embodiment) is substantially greater than the size of a typical perforation (about one quarter inch), and because the patch is formed from spring-steel which forces the patch against the wall of the well casing, an effective seal against the perforation is achieved. Due to the comparatively thin wall thickness of the patch (preferably on the order of about .008 inches for a 3.5 inch wellbore) only a minimal reduction in diameter of the well casing occurs. Therefore, most downhole tools may still be used in the patched well and a subsequent patch may be deployed farther down the well if desired.

It will be appreciated that an improved method for sealing perforations in oil well casings has been presented and that the new method may significantly extend the working life of steam injection oil wells by sealing unneeded perforations. It will also be appreciated that the present invention casing patching tool may be used in any situation where it is desirable to seal a hole or perforation in a tube or pipe. In the field of oil production, the prevention of water infiltration in wells due to holes or cracks at casing joints is one such additional application. Those skilled in the art will also understand that the invention may be scaled up, or down, in size and weight and used to seal leaks in pipes or tubes of virtually any size. In addition, because the delivery tool uses hydraulic force to deploy the patch, there is no need for the tool to be in a downwardly facing vertical position. The tool may function at

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any angle. Nor is a lowering cable required. In other applications, lightweight versions of the tool may be deployed in  
5 tortuous piping having long horizontal traverses using an appropriately designed hydraulic hose. Other contemplated applications for the present invention include sealing leaks in water and sewage lines. While only the presently preferred  
10 embodiments have been described in detail, as will be apparent to those skilled in the art, modifications and improvements may be made to the system and method disclosed herein without departing from the scope of the invention. Accordingly, it is not intended that the invention be limited except by the appended  
15 claims.

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